series; the thorough and, so far as possible, exhaustive study of the complex and double salts and, finally, the determination of the atomic masses of the elements with all the precision of which the subject admits, and in the spirit of Stas, of Richards and of Morley.

WOLCOTT GIBBS.

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*A HALF-CENTURY OF EVOLUTION, WITH SPECIAL REFERENCE TO THE EFFECTS OF GEOLOGICAL CHANGES ON ANIMAL LIFE.**

ONLY a little less than fifty years have passed since the publication of Darwin's Origin of Species, and the general acceptance by naturalists of the theory of descent. Since 1848 the sciences of embryology, cytology and comparative anatomy based on embryology, or, as it is now called, morphology, have been placed on a firm foundation. It is but little over half a century since the uniformitarian views of Lyell were promulgated. The cell doctrine was born in 1839; the view that protoplasm forms the basis of life was generally received forty years since; fifty years ago the doctrine of the conservation of forces was worked out, and already by this time had the idea of the unity of nature dominated the world of science.

On the fiftieth anniversary, therefore, of our Association, it may not be out of place, during the hour before us, first, briefly to inquire into the present state of evolution and its usefulness to zoologists as a working theory, and then to dwell more at length on the subject of the effect of geological changes on animal life.

The two leading problems which confront us as zoologists are: What is life? and How did living beings originate? We must leave to coming centuries the solution of the first question, if it can ever be solved; but we can, as regards the second, congratulate ourselves that, thanks to Lamarck, Darwin and others, in our day and generation, a reasonable and generally accepted solution has been reached.

*Address of the Vice-President before Section F.—Zoology—of the American Association for the Advancment of Science, August 22, 1898.

Time will not allow us to attempt to review the discoveries and opinions which have already been discussed by the founders and leaders of the different schools of evolutionary thought, and which have become the common property of biologists, and are rapidly permeating the world's literature.

It may be observed at the outset that, if there is any single feature which differentiates the second from the first half of this century, it is the general acceptance of the truth of epigenetic evolution as opposed to the preformation or incasement theory, which lingered on and survived until a late date in the first half of the present century.*

*The theory of incasement (*emboîtment*), propounded by Swammerdam in 1733, was that the form of the larva, pupa and imago of the insects pre-existed in the egg, and even in the ovary, and that the insects in these stages were distinct animals contained one inside the other, like a nest of boxes, or a series of envelopes one within the other; or, in his own words: "*Animal in animali, seu papilio intra erucam reconditus.*" Réaumur (1734) also believed that the caterpillar contained the form of the chrysalis and butterfly, saying: "Les parties des papillon cachées sous le fourreau de chenille sont d'autant plus faciles à trouver que la transformation est plus proche. Elles y sont neanmoins de tout temps." He also believed in the simultaneous existence of two distinct beings in the insect. "Il serait très curieux de connaître toutes les communications intimes qui sont entre la chenille et le papillon. * * * La chenille hache, broye, digere les aliments qu'elle distribué au papillon; comme les mères préparent ceux qui sont portés aux fœtus. Notre chenille en un mot est destineé à nourrir et à defendre le papillon qu'elle renferme." (Tome i, 8e Mémoire, p. 363.)

It was not until 1815 that Herold exploded this error, though Kirby and Spence in 1828, in their Introduction to Entomology, combated Herold's views and maintained that Swammerdam was right. As late as 1834, a century after Swammerdam, Lacordaire, in his Introduction à l'Entomologie, declared that 'a caterpillar is not a simple animal, but compound,' and he actually goes so far as to say that 'a

The establishment of the epigenetic view is largely due to exact investigation and modern methods of research, but more especially to the results of modern embryology and to the fairly well digested facts we now have relating to the development of one or more types of each class of the animal kingdom.

To use a current phrase, the evolution theory as now held has come to stay. It is the one indispensable instrument on which the biologist must rely in doing his work.

caterpillar, at first scarcely as large as a bit of thread, contains its own teguments threefold and even eightfold in number, besides the case of a chrysalis, and a complete butterfly, all lying one inside the other.' This view, however, we find is not original with Lacordaire, but was borrowed from Kirby and Spence without acknowledgment. These authors, in their Introduction to Entomology (1828), combated Herold's views and stoutly maintained the old opinions of Swammerdam. They based their opinions on the fact, then known, that certain parts of the imago occur in the caterpillar. On the other hand, Herold denied that the successive skins of the pupa and imago existed as germs, holding that they are formed successively from the '*rete mucosum*,' which we suppose to be the hypodermis of later authors. In a slight degree the Swammerdam, Kirby and Spence doctrine was correct, as the imago does arise from germs, *i. e.*, the imaginal disks of Weismann, while this was not discovered by Herold, though they do at the outset arise from the hypodermis, his *rete mucosum*. Thus there was a grain of truth in the Swammerdam, Kirby and Spence doctrine, and also a mixture of truth and error in the opinions of Herold.

The discovery by Weismann of the imaginal discs or buds of the imago in the maggot of the fly, and his theory of histolysis, or of the more or less complete destruction of the larval organs by a gradual process, and his observation of the process of building up of the body of the imago from the previously latent larval buds, was one of the triumphs of modern biology. It is, therefore, not a little strange to see him at the present day advocating a return to the preformation views of the last century in the matter of heredity. Of course, it goes without saying, as has always been recognized, that there is something in the constitution of one egg which predestines its becoming an insect, and in that of another which destines it to produce a chick.

It is now almost an axiomatic truth that evolution is the leaven which has leavened the whole lump of human intellectual activity. It is not too much to claim that evolutionary views, the study of origins, of the beginning of organic life, the genesis of mental phenomena, of social institutions, of the cultural stages of different peoples and of their art, philosophy and religion—that this method of natural science has transformed and illuminated the philosophy of the present half-century.*

It is naturally a matter of satisfaction and pride to us as zoologists that, though evolution has been in the air from the days of the Greek philosophers down to the time of Lamarck, the modern views as to the origin of variations, of adaptation, of the struggle for existence, of competition, and the preservation of favored organs or species by selection, are the products of single-minded zoologists like Darwin, Wallace, Fritz Müller, Semper and Haeckel. It is

* It is worthy of mention that just fifty years ago in his 'Future of Science,' written in 1848, at the age of 25, Renan, who perhaps first among philosophers and students of comparative philology adopted the scientific method, *i. e.*, the patient investigation of as wide a range of facts as possible, wrote: "I am convinced that there is a science of the origins of mankind and that it will be constructed one day, not by abstract speculation, but by scientific researches. What human life in the actual condition of science would suffice to explore all the sides of this single problem? And still, how can it be resolved without the scientific study of the positive data? And if it be not resolved how can we say that we know man and mankind? He who would contribute to the solution of this problem, even by a very imperfect essay, would do more for philosophy than by half a century of metaphysical meditation" (p. 150). Again he says: "The great progress of modern thought has been the substitution of the category of *evolution* for the category of the '*being;*' of the conception of the relative for the conception of the absolute, of movement for immobility. Formerly everything was considered as 'being' (an accomplished fact); people spoke of law, of religion, of politics, of poetry in an absolute fashion. At present everything is considered as in the process of formation" (p. 169).

the work of these men, supplemented by the labors of Spencer and of Huxley, and the powerful influence of the botanists Hooker and Gray, all of whom contributed their life-long toil and efforts in laying the foundation stones of the theory, which has brought about its general acceptance among thinking men. It is these naturalists, some of them happily still living, who have worked out the principle of evolution from the generalized to the specialized, from the simple to the complex, from chaos to cosmos.

The doctrine of evolution has been firmly established on a scientific basis by many workers in all departments of biology, and found not only to withstand criticism from every quarter, but to be an indispensable tool for the investigator. The strongest proof of its genuine value as a working theory is that it has, under the light shed by it, opened up many an avenue of inquiry leading into new fields of research. It is based on the inductive method, the observation and arrangement of a wide series of facts. Moreover, it explains a vast complex of facts, and enables us to make predictions, the true test of a scientific theory. Biology is not an exact science, hence the theory is not capable of demonstration like a problem in mathematics, but is based on probabilities, the circumstantial evidence being apparently convincing to every candid, well-trained mind.

The methods and results of natural science, based as they now are on evolutional grounds, have, likewise, appealed to the historian, the philologist, the sociologist, and the student of comparative religion, whose labors begin with investigations into the origins.

It goes without saying that, thanks to the initiative of the above-named zoologists, every department of intellectual work and thought has been rejuvenated and rehabilitated by the employment of the modern scientific method. All inquiring minds appreciate the fact that, throughout the whole realm of nature, inorganic, as well as organic, physical, mental, moral and spiritual, there was once a beginning, and that from a germ, by a gradual process of differentiation or specialization, the complex fabric of creation has, by the operation of natural laws and forces, been brought into being. All progress is dependent on this evolutionary principle, which involves variation, adaptation, the disuse or rejection of the unfit, the use or survival of the fittest, together with the mechanical principle of the utmost economy of material.

Though the human mind has its limitations, and the chief arguments for evolution have been drawn from our observations of the history of our own planet, and of the life existing upon it, the nebular hypothesis teaches us that the same process has dedetermined the origin of other worlds than ours and applies in fact to all the other members of our solar system, while with little doubt the principles may be extended to the entire universe.

At all events, evolutionary methods of thinking have now become a second nature with philosophic, synthetic minds, and to such any other view is inconceivable. We teach evolution in our colleges and universities, and the time is rapidly approaching, and in some instances has already come, when nature studies, and the facts of biology forming the grounds of the evolutionary idea, will be taught in our primary and secondary schools.

The rapidity with which evolutionary conceptions have taken root and spread may be compared to the rankness of growth of a prepotent plant or animal on being introduced into a new territory where it is free from competition. It has, indeed, swept everything before it, occupying a field of thought which hitherto had been unworked by human intelligence.

The immediate effect, and a very happy

one, of the acceptance of the theory of descent on working zoologists is to broaden their minds. Collectors of insects and shells, or of birds and mammals, instead of being content simply to acquire specimens for their cabinets, are led to look during their field excursions for examples of protective mimicry, or to notice facts bearing on the immediate cause of variation. Instead of a single pair of specimens, it is now realized that hundreds and even thousands collected from stations and habitats wide apart are none too many for the study of variation as now pursued.

The race of 'species grinders' is diminishing, and the study of geographical distribution, based as it is on past geographical changes and extinctions, is now discussed in a far more philosophical way than in the past. The most special results of work in cytology and morphology are now affording material for broad work in phylogeny and heredity.

On the other hand, it must be confessed that, as the result of the acceptance of evolutionary views, our literature is at times flooded with more or less unsound hypotheses, some tedious verbiage and long-winded, aërial discussions, based rather on assumptions than on facts. But on the whole, perhaps, this is a healthy sign. Too free, exuberant growths will be in the long run lopped off by criticism.

One tendency should be avoided by younger students, that of too early specialization, and of empirical work without a broad survey of the whole field. In some cases our histologists and morphologists rise little above the intellectual level of species describers. Expert in the use of the microtome and of reagents, they appear to have but little more general scientific or literary culture than high-class mechanics. The chief antidote, however, to the danger of narrowness is the lessons derived from evolutionary thought and principles.

Finally, as a proof of the value of evolutionary ideas to the present generation, let us suppose for a moment, if it were conceivable, that they should be blotted out. The result, it is safe to say, would be equivalent to the loss of a sense.

It is a matter of history that when a new idea or principle, or a new movement in philosophy or religion, arises it at first develops along the line of least resistance; the leaders of the new thought acquire many followers or disciples. Soon the latter outstrip their teachers, and go to greater extremes; modifications of the original simple condition or theory occur, and as the final result there arise schisms and differentiations into new sects. This has happened in science, and already we have evolutionists divided into Lamarckians and Darwinians, with a further subdivision of them into Neolamarckians and Neodarwinians, while the latter are often denominated Weismannians. Some prefer to rely on the action of the primary factors of evolution; others believe that natural selection embraces all the necessary factors, while still others are thoroughly persuaded of its inadequacy.

The result of this analytical or differentiating process will probably be an ultimate synthesis, a belief that there is a complex of factors at work. Of these factors those originally indicated by Lamarck, with the supplementary ones of competition and natural selection bequeathed by Darwin, are the most essential and indispensable, and it is difficult to see how they can be displaced by other views. Meanwhile all agree, and it was never more firmly established than at this moment, that there is, and always has been, unceasing energy, movement and variation, a wonderful adaptation and harmony in nature, between living beings and their surroundings.

The present status of evolution in its different phases or attitudes since the time of

the appearance of Darwin's Origin of Species may be roughly pointed out as follows:

1. The claim by some thinkers of the inadequacy of Darwinism, as such, or Natural Selection, to account for the rise of new species, and the assignment of this factor to what they believe to be its proper place among the other factors of organic evolution.

2. The renascence of Lamarckism under the name of Neolamarckism, being Lamarckism in its modern form. This school relies on the primary factors of evolution, on changes in the environment, such as the agency of the air, light, heat, cold, changes in climate, use and disuse, isolation, and parasitism, while it regards natural, sexual, physiological, germinal and organic selection, competition or its absence, and the inheritance of characters acquired during the lifetime of the individual, as secondary factors, calling into question the adequacy of natural selection as an initial factor.

3. The rise of the Neodarwinian school. While Darwin, soon after the publication of the Origin of Species, somewhat changed his views as to the adequacy of natural selection, and favored changes in the surroundings, food, etc., as causes of variation, his successors, Wallace, Weismann and others, believe in the 'all-sufficiency' of natural selection. Weismann also invokes panmixia, or the absence of natural selection, as an important factor; also amixia, and denies the principle of inheritance of acquired characters, or use-inheritance.

4. A third school or sect has arisen under the leadership of Weismann, who advocates what is in its essence apparently a revival of the exploded preformation, encasement or 'evolution' theory of Swammerdam, Bonnet and Haller, as opposed to the epigenetic evolutionism of Harvey, Wolff, Baer and the majority of modern embryologists. On the other hand, there are some embryologists who appear to accept the combined action of epigenesis and evolution in development.

5. Attention has been concentrated on the study of variations and of their cause. Opinion is divided as to whether variation is fortuitous or definite and determined. Many now take exception to the view, originally held by Darwin, that variations are purposeless and fortuitous, believing that they are, for example, dependent on changes in the environment which were determined in early geological periods. For definite variations Eimer proposes the term orthogenesis. Minute variations dependent on climatic and other obscure and not readily appreciable causes are now brought out clearly by a system of varied and careful quantitative measurements.

6. More attention than formerly is given to the study of dynamical evolution, or kinetogenesis; to the effect of external stimuli, such as intermittent pressure, mechanical stresses and tensions by the muscles, etc., on hard parts. Originally suggested by Herbert Spencer, that the ultimate cause or mechanical genesis of the segmentation of the vertebrate skeleton was due to transverse strains, the segmentation of the bodies of worms and arthropods, as well as of vertebrates, has been discussed by recent workers (Rider, Cope, Meyer, Tornier, Hirsch and others.) Here should be mentioned the work done in general physiology, or morphogenesis, by Verworn, Davenport and others. Also the discoveries of Pasteur, and the application by Metschnikoff and of Kowalevsky of phagocytosis to the destruction and renewal of tissues during metamorphosis, bear closely on evolutional problems.

7. A new field of research, founded by Semper, Vilmorin and Plateau, and carried on by DeVarigny, is that of experimental evolution, involving the effects of artificial changes of the medium, including temperature, food, variation in the volume of water

and of air, absence of exercise, movement, etc. Also should be added horticultural experiments which have been practised for many years, as well as the results of acclimatization.

Here should be mentioned the experiments bearing on the mechanics of development (Entwickelungsmechanik der Organismen), or experimental embryology, of Oscar Hertwig, Roux, Driesch, Morgan and others, and the curious results of animal grafting and of mutilations of the embryos, obtained by Born and others, as well as the regeneration of parts. The remarkable facts of adaptation to new and unfavorable conditions of certain embryos are as yet unexplained, and have led to considerable discussion and research.

8. The *a priori* speculations of Darwin, Galton, Spencer, Jaeger, Nusbaum, Weismann and others, based on the results of the labors of morphologists and cytologists, have laid the foundation for a theory of the physical basis of heredity, and for the supposition that the chromatine in the nucleus of reproductive cells is the bearer of heredity. The theory has already led to prolonged discussions and opened up new lines of work in cytology and embryology.

9. The subject of instinct, discussed from an evolutional point of view, both by morphologists and psychologists, particularly by Lloyd Morgan, has come to the front, while mental evolution has been discussed by Romanes and others.

With all these theories before us, these currents and counter-currents in evolutional thought bearing us rapidly along, at times perhaps carrying us somewhat out of our depth, the conclusion of the whole matter is that in the present state of zoology it will be wise to suspend our judgment on many theoretical matters, to wait for more light and to confine our attention meanwhile to the observation and registration of facts, to careful experiments and to repeated tests of mere theoretical assumptions.

Meanwhile we may congratulate ourselves that we have been born and permitted to labor in this nineteenth century, the century which in zoological science has given us the best years of Lamarck's life, a Cuvier, a Darwin, a Von Baer, an Owen, an Agassiz, a Haeckel, a Spencer, and a Huxley—the founders of modern zoology—who have sketched out the grander features of our science so completely that it will, perhaps, be the work of many coming years to fill in the details.

GEOLOGICAL CAUSES OF VARIATION AND OF THE EXTINCTION AND RENEWAL OF SPECIES.

The most immediate and efficient cause of variation appears to be changes of environment or of the physical conditions of existence. These, besides the agencies of gravity, electricity, of the atmosphere, light, heat, cold, food, etc., comprise geological changes or revolutions in the topography of the earth's surface at different periods. The latter causes appear to have had much to do with the process of extinction and renewal of plants and animals.

While the doctrine of the effect on animals of a change of environment was suggested very early in this century and forms the corner stone of Lamarckism, Wallace was, after De la Beche,* and especially Lyell†, the first in recent times, in an essay published in 1855, to call attention to this subject thus:

"To discover," he says, "how the extinct species have from time to time been replaced by new ones down to the very latest geological period, is the most difficult, and

*Researches in Theoretical Geology. New York, 1837, p. 217. Quoted by Woodworth, p. 220.

† Principles of Geology, 1830–1832.

at the same time the most interesting, problem in the natural history of the earth."*

Still more recently † he remarks:

"Whenever the physical or organic conditions change to however small an extent, some corresponding change will be produced in the flora and fauna, since, considering the severe struggle for existence and the complex relations of the various organisms, it is hardly possible that the change should not be beneficial to some species and hurtful to others."

Two conclusions are now generally accepted. The first is, that the most complete evidence of evolution is afforded by paleontology. Huxley's vigorous affirmation, that the primary and direct evidence in favor of evolution can be furnished only by paleontology, has been greatly strengthened by recent discoveries. The second is that biological evolution has been primarily dependent on physical and geological changes.

It may not be unprofitable for us as zoologists to pass in review some of the revolutions in geological history, particularly as regards our own continent, some important details of which have recently been worked out by our geologists, and to note the intimate relation between these revolutions and the origination not only of new species, but of new faunæ, and, indeed, at certain epochs, of new types of organic life.

1. *Precambrian revolutions.* That immensely long period which intervened between the time when our planet had cooled down and become fitted for the existence of animal life, and the opening of the Cambrian period, was evidently a time of the geologically rapid production of ordinal and class types of invertebrate life. This is strongly suggested by the fact that a large proportion of the Cambrian classes embrace forms as highly specialized as their successors of the present day, so that we are compelled to look many ages back of the Cambrian for the appearance of their generalized ancestral forms.

* Natural Selection, p. 14.

† Darwinism, 1889, p. 115.

Of the eight branches, of phyla, of the animal kingdom, the remains of seven, or all except the vertebrates, have been found in Cambrian strata. Adopting the kind of statistics employed by Professor H. S. Williams in his admirable Geological Biology, but with some changes necessitated by a little different view as to the number of classes living at the beginning of the Cambrian period, it appears that 13 out of 26 classes of the animal kingdom, occurring in a fossil condition, already existed in the Cambrian and, if we throw out from the vertebrate classes those without a solid skeleton (the Enteropneusta or Balanoglossus, Tunicates, Amphioxus and the lampreys) 13 out of 22. Also, if we exclude the land forms (Arachnida, Myriopoda and insects), 13 out of 19, and then throwing out the five vertebrate classes found in a fossil state, of 14 invertebrate marine classes 13 occur in the Cambrian.* With little doubt flat-worms, nemerteans, Nematelminthes and Gephyrea existed then, and probably the representatives of other classes, of which no traces will ever occur.

We shall for our present purpose follow the classification of the U. S. Geological Survey and restrict what was formerly called the Archean to the fundamental gneiss and crystalline schists of an unknown thickness, and accept the Algonkian, as comprising the Huronian and Keeweenawan formations. We may assume that the first beginnings of life took place toward the end of the Archean and that the more or less rapid differentiation of class types went on during Algonkian time. This view is fortified by the statement of Wal-

* Should the Polyzoa be traced to the Cambrian, as is not at all impossible, the fact would remain that every class of marine invertebrates with solid parts is represented in the Cambrian.

cott that a great orographic movement, followed by long-continued erosion, took place between the Archean and Algonkian ages.

Taking as an example of the nature of the Algonkian changes one region alone, the Lake Superior region, where the stratigraphical record is more complete, we have: 1, the Lower Huronian schists, limestone, quartzites, conglomerates, etc., with their eruptives, closely folded and attaining a maximum thickness of probably over 5,000 feet.

2. The Upper Huronian, unconformable to the Lower, a series of more gently folded schists, slates, quartzites, conglomerates, interbedded and cut by trap, with a maximum thickness of 12,000 feet. In the Animikie quartzites of this age have, according to Selwyn, been detected a track of organic origin, in the Minnesota quartzites Lingula-like forms, as well as obscure "trilobitic-looking impressions; while carbonaceous shales are abundant."

3. Between these Huronian rocks and the true Cambrian series are interpolated the Keweenawan clastic rocks, with a maximum thickness of 50,000 feet. Though these beds are by some high authorities referred to the Cambrian, the fact remains that this series, whether Cambrian or Algonkian, is unconformable to the Huronian, and composed of fragmental rocks, the upper division being 15,000 feet thick, and consisting wholly of detrital material largely derived from the volcanoes of the same series. Between each series is an unconformity representing an interval of time long enough for the land to have been raised above the seas, for the rocks to be folded, to have lost by erosion thousands of feet, and for the land to sink below the surface of the ocean.

Again, between the Precambrian and Cambrian there was, according to Walcott, a great uplift and folding of rock, succeeded by long-sustained erosion, over all the continental area. It was not, however, he states, 'as profound as the one preceding Algonkian time, as is proved by the more highly contorted and disturbed Archean rocks beneath the relatively less disturbed Algonkian series.' *

The evidence of the existence of life-forms in the Huronian and Keweenawan times is indicated by the presence of thick beds of graphitic limestone, beds of iron carbonates, and by a great thickness of carbonaceous shales, which are represented by graphitic schists in the more altered strata. In the Animikie rocks on the northern shores of Lake Superior, Ingalls finds abundant carbon, and it is said that in certain mines and openings rock-gas forms to a considerable extent. Also small quantities of rock may even be obtained which will burn. "These substances must result from the ordinary processes which produce rock-gas and coal in the rocks of far later age. The hydrocarbons which occur so abundantly in the slightly metamorphosed shales of the Huronian about Lake Superior must be of organic origin," and, if so, the graphitic schists of the same system "are in all probability only those hydrocarbonaceous shales in a more altered condition."

As to the fossils actually detected in what are by some geologists regarded as Algonkian strata, Winchell has detected a Lingula-like shell in the pipestones of Minnesota. Selwyn has described traces of animals in the Upper Huronian of Lake Superior. Murray, Howley and Walcott have discovered several low types in the Huronian of Newfoundland; *i. e.*, a mollusc (*Aspidella terranovica*)† and traces of a worm (*Aren-*

* The North American Continent during Cambrian Time. Twelfth Ann. Rep. U. S. Geological Survey, p. 544.

†Dr. G. F. Matthew writes me as follows regard ing this supposed fossil: "I have seen *Aspidella terranovica* in the museum at Ottawa and doubt its organic origin. It seems to me a slickensided mud-

icolites spiralis), the latter said to occur in the primordial rocks of Sweden. Walcott reports the discovery, in the Grand Cañon of the Colorado, of the following Precambrian fossils: "A minute discinoid or patelloid shell, a small Lingula-like shell, a species of Hyolithus, and a fragment of what appears to have been the pleural lobe of the segment of a trilobite belonging to a genus allied to the genus *Olenellus*, *Olenoides*, or *Paradoxides*. There is also an obscure *Stromatopora*-like form that may not be organic.

Here should be noted the discovery, in 1896, of *Radiolaria** in calcareous and cherty rocks of 'undoubted Precambrian age' near Adelaide, Australia (*Nature*, Dec. 24, 1896, p. 192); the detection of fossils in the Archean of Brittany, and of three veins of anthracite 'in crystalline schists of Archean age' in Ecuador.

At St. John, New Brunswick, that able and experienced geologist, Dr. G. F. Matthew, has detected fossils in strata which he refers to the upper Laurentian. They occur in three horizons. The lowest series is composed of a quartzite containing fragments of the skeleton of hexactinellid sponges allied to Cyathospongia. In the upper limestone of the second horizon were collected calcareous coral-like structures resembling *Stromatopora rugosa*. In the third and uppermost horizon, consisting of beds of graphite, occurred great numbers of spicules of apparently hexactinellid sponges. "Between this upper Laurentian system and the basal Cambrian occurs," says Matthew, "a third system, the Coldbrook and Coastal, Huronian, which has given conglomerates to the Cambrian and has a great thickness." He also tells us that the Precambrian St. Etcheminian beds at St. John, consisting of red and green slates and shales, have a meagre fauna comprising Protozoa, brachiopods, echinoderms, molluscs, with plentiful worm burrows and trails. In commenting on this subject Sir J. W. Dawson remarks that these Etcheminian strata rest on Huronian rocks which, near Hastings, Ontario, contain worm burrows, sponge-spicules, 'and laminated forms comparable to Cryptozoon and Eozoon.' (*Nature*, Oct. 15, 1896, p. 585.)

Even allowing room for error in the correlation of these formations, and in regarding some of these rocks as no older than Cambrian, yet on the whole the result appears to be that abundant vegetation existed in Precambrian times, which was converted into graphite, while representatives of seven classes were perhaps already in existence previous to the Cambrian period.

The following lists give a comparative view of the classes of the periods in question:

Precambrian Classes.	*Cambrian Classes.*
Rhizopoda (Radiolaria).	Rhizopoda (Foraminifera and Radiolaria).
Porifera (Hexactinellid Sponges).	Porifera (Sponges).
	Hydrozoa (Meduse and Graptolites).
Actinozoa (Corals).	Actinozoa (Corals).
Brachiopoda.	Brachiopoda.
Annelida.	Annelida.
	Crinoidea.
	Asteroidea.
	Lamellibranchiata.
Mollusca.	Gastropoda (including Pteropoda*).
	? Cephalopoda (Orthoceras?).
Trilobita.	Trilobita.
	Crustacea.

concretion striated by pressure. I have found similar objects in the Etcheminian olive gray beds below the St. John group."

*Dr. Matthew likewise informs me: "The (*Radiolarian*?) rocks of Adelaide, South Australia, Mr. Howchin writes to me he now finds to be Lower Cambrian. He has found Archæocyathus in them; but this is not proof of *Lowest* Cambrian, as the genus is found in the *Paradoxides* beds of the south of France."

* Dr. Matthew writes me that he doubts if Hyalithoid shells should be referred to Pteropoda. "Pelseneer quite repudiates them; and to me their heavy shells, and frequent habitat on rough shores, do not speak of the fragile Pteropoda."

It would seem from these data that the physical condition of the sea and atmosphere was favorable to the existence of types for aught we know quite or nearly as highly specialized as those of the same classes now in existence. Life and nature in the Precambrian went on, so far as we can tell, much as in Cambrian times. Though locally there are breaks in the continuity of geological processes, yet probably over the world generally there was a continuity of geological phenomena, and on the whole a tolerably unbroken series of organic forms.

It is obvious, however, that in the regions thus far examined, the Precambrian, whether we include the Archean or not, more than at any time since, though the land areas are by some considered to be of small extent, was a period of widespread and profound changes in the distribution of land and sea. While it is generally supposed that the extent of the continental areas at the beginning of Paleozoic time was small, forming islands, Walcott is inclined to the belief that it was very considerable, stating:

"The continent was larger at the beginning of the Cambrian period than during any epoch of Paleozoic time, and probably not until the development of the great fresh-water lakes of the Lower Mesozoic was there such a broad expanse of land between the continental platform between the Atlantic and Pacific Oceans. The agencies of erosion were wearing away the surface of this Algonkian continent and its outlaying mountain barriers to the eastward and westward, when the epoch of the Lower Cambrian or Olenellus zone began. The continent was not then new. On the contrary, it was approaching the base level of erosion over large portions of its surface. The present Appalachian system of mountains was outlined by a high and broad range, or system of ranges, that extended from the present site of Alabama to Canada, and subparallel ranges formed the margins of basins and straits to the east and northeast of the northern Paleo-Appalachian or the Paleo-Green Mountains, and their northern extension toward the Precambrian shore-line of Labrador. The Paleo-Adirondacks joined the main portion of the continent, and the strait between them and the Paleo-Green Mountains opened to the north into the Paleo-St. Lawrence Gulf, and to the south extended far along the western side of the mountains and the eastern margin of the continental mass to the sea that carried the fauna of the Olenellus epoch around to the Paleo-Rocky Mountain trough." (*l. c.* p. 562.)

Remarking on the habitat, or nature and extent of the sea-bottom tenanted by the Olenellus or Lower Cambrian fauna, Walcott remarks:

"One of the most important conclusions is that the fauna lived on the eastern and western shores of a continent that, in its general configuration, rudely outlines the North American continent of to-day. Strictly speaking the fauna did not live upon the outer shore facing the ocean, but on the shores of interior seas, straits, or lagoons that occupied the intervals between the several ridges that rose from the continental platform east and west of the main continental land surface of the time." (*l. c.* p. 556.)

Dana had previously (1890) claimed that the earth's features even to many minor details were defined in Archean time (evidently referring to all Precambrian time) and that 'Archean conditions exercised a special and even detailed control over future continental growth.' May not this idea be extended to include the life of the Precambrian, and may we not suppose that biological variations and evolutions were predetermined to some degree at least by the geological conditions of these primeval ages? The continental masses were then

foreshadowed by submarine plateaus covered by shallow seas, the deeper portions of the ocean basins not being affected by these oscillations, extensive as they were.

The time which elapsed between the end of the Laurentian and the beginning of the Cambrian was immense, or at least as long as the entire Paleozoic era. Walcott estimates the length of the Algonkian at 17,500,000 years. This length of time, or even a portion of it, was long enough for the origination and establishment of those classes, whose highly specialized descendants flourished in the Cambrian. Referring to the Precambrian strata Walcott states :

"That the life in the pre-Olenellus seas was large and varied there can be little, if any, doubt. The few traces known of it prove little of its character, but they prove that life existed in a period far preceding Lower Cambrian time, and they foster the hope that it is only a question of search and favorable conditions to discover it." *

Here the imagination of the zoologist may be allowed for the moment free scope to act. It is perhaps not hazardous to surmise that in the early centuries or millenniums of the Huronian there arose, from some aggregated or compound infusorian, the prototype of the sponges.

From some primitive gastrula which became fixed to the Huronian sea-bottom may have arisen the hydroid ancestor of the Cœlenterates ; owing to its fixed mode of life, the primitive digestive cavity opened upwards, being held in place by the septa, so that the vase-shaped body, growing like a plant, with the light striking upon it from all sides, assumed a radical symmetry. Before the beginning of the Cambrian, for we know Aurelia-like forms abounded on the Cambrian coasts, medusæ budded out from some hydroid polyps, became free-swimming, and as a result of their living at the surface became transparent, and thus shielded from the observation of whatever enemies they had, multiplied in great numbers.

* The fauna of the Lower Cambrian or Olenellus zone. Tenth Annual Report of the U. S. Geological Survey, 1888-89.

From some reptant gastræa there may have sprung, in these primeval times, an initial form with a fore-and-aft, dorso-ventral and bilateral symmetry, which gave origin by divergent lines of specialization to flat-worms, nemertean and round-worms, as well as Rotifera, and other forms included among the Vermes. It is probable that the Trematodes and Cestodes, especially the latter, whose organs have undergone such reduction by parasitism, and some of which through disuse have totally disappeared, did not evolve until some time after the appearance of molluscs and fishes.

When existence in these early plastic vermian forms was confined to boring in the mud and silt, the body became cylindrical, as in some nemerteans, and in the thread-worms ; some of the latter forms, boring into the mud, became parasites, entering the bodies of other animals which serve as their hosts.

At about this time certain worms, as the simple mechanical result perhaps of threading their way over or through the rough gravelly bottom, became segmented. The establishment of a segmental structure, brought about by the serpentine mode of progression in the direction of least resistance, resulted in the origination of a succession of levers. Following this annulated division of the dermo-muscular tube of worms, was the serial or segmental arrangement of the internal organs, *i. e.*, the nervous, excretory, reproductive and glandular, and, in a less degree, the circulatory.

In certain of these primitive protannelids, as the result perhaps of external stimuli intermittently applied, bristles originated to aid in progression, and finally the segmentally arranged lateral flaps of the

skin, the parapodia, which served as swimming organs. Other nepionic forms, at first free swimming, became fixed and protected by two valves as in the Brachiopoda, which owe their success in Precambrian times to to their fixed and protected bodies.

Not long after the annelid type became established that of the echinoderms apparently diverged from some nepionic worm, like a trochosphere. In such a form there was a tendency to the deposition of particles and plates of lime in the walls of the body, and the type, becoming fixed at the bottom, or at least nearly stationary, and meanwhile more or less protected by a calcareous armor, lost its originally bilateral and acquired a radial symmetry.

But no echinoderms have yet been detected in Percambrian rocks, which, however, have revealed arthropods, as shown by the traces of trilobites, and this tends to indicate that radial symmetry is an acquired, not a primitive characteristic.

At this time was solved the problem of the origination of a type of body, and of supports for it either in walking or in swimming, which should fulfill the most varied conditions of life, and this type, the arthropodan, as events proved, was that fitted for walking over the sea-bottom, for swimming or for terrestrial locomotion; nor was the idea of segmentation both in trunk and limbs discarded when the type culminated in flying forms—the insects.

The Arthropoda, as the record shows, first represented by trilobites, which structurally are nearer the annelids than Crustacea, was destined to far outnumber in individuals, species, orders and classes any other phylum. Fundamentally worm-like or annelid in structure, the body consisted of a linear series of stiff levers, and was supported by limbs segmented in the same way. The variations of the arthropodan theme are greater than in any other groups, and nature, so to speak, succeeded most admirably in this type, with the exception of the Trilobita, which was the first class of the phylum to appear and the first to disappear. The evolution of jointed limbs was accomplished in the most economical and direct way. The parapodia were perhaps utilized, and at first retaining their form in swimming phyllopods, afterwards from being used as supports, became cylindrical and jointed. All this modification of monotypic forms and evolution from them to other types was accomplished not very late perhaps in the Precambrian. After the specialization of the antennæ and of the trunk-segments of the trilobites was worked out, all the postantennal appendages being alike, there ensued in some descendant of another vermian ancestor a further differentiation of the postantennal appendages into mandibles, maxillæ, maxillipedes, thoracic ambulatory legs, and abdominal swimming feet, as worked out in the more specialized members of the class of Crustacea.

As soon as the crustacean type became established, the conditions must have been most favorable for its rapid differentiation along quite divergent lines, for in the Cambrian strata occur the remains of four orders, viz., the Cirrhipedia, Ostracoda, Phyllopoda, the sole Cambrian form (*Protocaris marshi* related to the modern Apus), and the Phyllocarida. Of these the barnacles and ostracodes, with their multivalve or bivalve carapaces, are the most specialized, and in the case of the former the process of modification due to this fixed mode of life must have required ages, as must also the development of that highly modified vermian type, the Brachiopoda.

Indeed, the three lines of descent which resulted in the arthropodan phylum, as it now exists, unless there were three independent phyla, were perhaps initiated before the Cambrian. These lines are (1) the Trilobita, with their probable successors the merostomes and arachnids, (2) the

Crustacea, and (3) the myriopods and insects. Of the third line Peripatus or a Peripatus-like form was the earliest ancestor, which, of course, must have been terrestrial in habits, though its forebears may have been some fresh-water leech-like worm. We venture to state it is not wholly impossible that so composite a type as Peripatus, which bears at least some of the marks of being a persistent type, took its rise on the continental land of the Precambrian.

In the Precambrian time was also solved the problem by the molluscs of producing a spiral univalve shell; for while a large proportion of the Gastropoda were protected by patella-like shells of simple conical form, with these coexisted in the lowest Cambrian forms with spiral shells, such as Platyceras and Pleurotomaria. The comparative abundance of those highly modified molluscs, the Pteropoda, in the lowest or Olenellus Cambrian strata, strongly suggests that their diverence from the more generalized gastropod stem and their adaptation to a surface or pelagic life must have taken place long anterior to the dawn of the Cambrian.*

With them must have lived a variety of other surface forms besides Rhizopoda, whose young served as their food. The members of all classes of the Cambrian were carnivorous, feeding on the protoplasm of the bodies of microscopic animals or on the eggs and young of their own species, some living on the bottom, and others at the surface. Of marine plants of the Cambrian there are but slight traces, and it is evident that what there were were restricted to the coasts and to s allow water. The old idea that plants originally served as the basis of animal life must be discarded. As at present no plant life exists below a few fathoms, a hundred perhaps at the most, and since below these limits the ocean depths are packed with animal life which exists entirely on the young or the adults of weaker forms, so must the rise and progress of animal life have been quite independent of that of plants. The lowest plants and animals may have evolved from some common bit of protoplasm, some protist, but the evolution of the animal types became very soon vastly more complex. The specialization of parts and adaptation to the environment were more thorough and rapid in the lowest animals evidently in consequence of the greater power of locomotion, and aggressiveness in obtaining food from living organisms, and the adaptability of animal life to various oceanic conditions, especially temperature, bathymetrical conditions and a varying sea-bottom.

This rapid differentiation and multiplication of different family, ordinal and class ancestral types went on without those biological checks which operated in later times, when the seas and land masses of the globe became more crowded. There was a comparative absence of competition and selection, this being due to the lack of predaceous carnivorous forms to produce that balance in nature which afterwards existed. The two most successful and abundant types were the trilobites and brachiopods; but the former were not especially aggressive in their habits, undoubtedly taking their food in a haphazard way by burrowing in the mud or sand, having much the same kind of appendages and the same feeding habits as Limulus. The brachiopods were fixed or burrowed in the sand, straining the microscopic organisms drawn into the mouth by the currents set up through the action of their ciliated arms. The most destructive and aggressive Cam-

* Dr. Matthew has discovered at St. John, N. B., a still lower and older bed, containing no Olenellus; but Foraminifera (Orbulina and Globigerina), sponges, Pteropoda, Pelagiella which was probably an oceanic Heteropod, very primitive branchiopods, with Ostracoda and six genera of trilobites.

brian animal known to us was the Orthoceratites, but its remains have not yet been detected below the 2d Cambrian zone. Even if some protocordate Balanoglossus, Ascidians or even Amphioxus had already begun their existence in these Precambrian times they could have caused but a little more destruction of life than their contemporaneous invertebrate allies. As the remains of Ostracodermi and sharks have been detected in Trenton strata, perhaps they originated in the Cambrian, when they must have been active forces in the elimination of those Precambrian soft-bodied animals which connected classes now quite wide apart.

The rapid increase in the Precambrian population was hastened by the probable fact that this, more than any subsequent period, was one of rapid migration and colonization. Vast areas of the shallow depths over the site of the embryo continent, more or less shut off from the main ocean by shoals, reefs and islands, were, by oscillations of the sea-bottom and land, opened up at various times to migrants from the older previously settled seas.

The nature of the Precambrian sediments shows that the more open sea-bottom was swept by tidal and ocean currents varying in strength and extent. The topography of the ocean bottom over what is now land must have been more diversified than at present. In the late ages of the Algonkian, owing to active competition and the struggle for existence in the overstocked areas, the process of segregation or geographical isolation was rapidly effected, and the migrants from the denser centers of growth pressed into the then uninhabited areas where, as new, vigorous and prepotent colonists, they broke ground and founded new dynasties.

At such times as these we can easily imagine that, besides the absence of competition, the Lamarckian factors of change of surroundings bringing about new habits and thus inducing new needs, the use and disuse of organs, together with the inheritance of characters acquired during the lifetime of the individual, operated then far more rapidly and in a much more thoroughgoing way than at any period since, while all through this critical, creative period, as soon as there was a sufficient diversity in the incipient forms and structures, a selective principle began to operate.

For forty years past, since the time of Darwin, the idea that these early forms were more rapidly evolved, and that they were more plastic than forms now existing, has constantly cropped out in the writings of our more thoughtful and studious paleontologists and biologists.

Darwin, in his Origin of Species, as quoted by Walcott with approval, remarked that it is indisputable that, before the lowest Cambrian stratum was deposited, long periods elapsed, as long as, or probably far longer than, the whole interval from the Cambrian age to the present day; and that 'during these vast periods the world swarmed with living creatures.' Darwin then adds: "It is, however, probable, as Sir William Thompson insists, that the world at a very early period was subjected to more rapid and violent changes in its physical conditions than those now occurring; and such changes would have tended to induce changes at a corresponding rate in the organism which then existed."

Professor Hyatt,* from his exhaustive studies on the Nautiloidea and Ammonoidea, concludes:

"These groups originated suddenly and spread out with great rapidity, and in some cases, as in the Arietidæ of the Lower Lias, are traceable to an origin in one well-defined species, which occurs in close proximity to the whole group in the lowest bed of the

*Phylogeny of an Acquired Characteristic. Proc. Amer. Phil. Soc., XXXII., p. 371.

same formation. These facts, and the acknowledged sudden appearance of large numbers of all the distinct types of invertebrates in the Paleozoic, and of all the greater number of all existing and fossil types before the expiration of Paleozoic time, speak strongly for the quicker evolution of forms in the Paleozoic, and indicate a general law of evolution. This, we think, can be formulated as follows: *Types are evolved more quickly and exhibit greater structural differences between genetic groups of the same stock while still near the point of origin than they do subsequently. The variations or differences may take place quickly in the fundamental structural characteristics, and even the embryo may become different when in the earliest period, but subsequently only more superficial structures become subject to great variations.**

If this applies to the evolution of these cephalopods in the Mesozoic, how much more rapidly and efficaciously did the principle operate in the Precambrian period, after the initial steps in the divergence of types from the unicellular Protozoon took place? The same law or fact obtains with the insects, the eight holometabolous orders having, so far as the evidence goes, originated at nearly the same geological date, near or soon after the close of the Paleozoic era. Williams also shows, from a study of the variations of *Atrypa reticularis*, that this species in its specific characters shows a greater degree of variability of plasticity in the earlier than in the later stages of its history. We thus conclude that after the simplest protoplasmic organisms originated, the greatest difficulties in organic development, *i. e.*, the origination of the founders of the different classes were, so to speak, met and overcome in Precambrian times. The period was one of the rapid evolution of types. As Williams† has well remarked:

*Geological Biology, p. 322.

†*L. c.* p. 347.

"The chief expansion of any type of organism takes place at a relatively early period in its life history. Since then, as with the evolution of the continent itself, the further progressive differentiation of marine invertebrate forms has, since the close of the Precambrian, been a matter of detail."

As well stated by Brooks, since the first establishment of the Cambrian bottom fauna, "evolution has resulted in the elaboration and divergent specialization of the types of structure which were already established, rather than in the production of new types."

In accepting the general truth of this statement, and its application to the marine or Cambrian types it may, however, be modified to some extent. For during the late Paleozoic was witnessed the evolution of the three tracheate, land-inhabiting, air-breathing classes of Arachnida, Myriopoda and insects, and of the air-breathing vertebrates, with limbs and lungs, comprising the four classes of amphibians, reptiles, birds and mammals.

ALPHEUS S. PACKARD.

(*To be concluded*).

BOTANICAL NOTES.

ASPARAGUS RUST.

DR. B. D. HALSTED, of the New Jersey Experiment Station, has issued a bulletin No. 129) on the Asparagus Rust, its treatment and natural enemies, which is of much botanical interest, since it gives good illustrations of all the stages in natural size, and under different magnifications. This rust was described by De Candolle in 1805, and given the name which it now bears, *Puccinia asparagi*. It has been known in Europe for a long time, but was unknown in the United States before 1896. In that year Dr. Halsted detected it in New Jersey, Delaware, Long Island and some portions of New England. In 1897 and 1898 it has